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International Olympiad in Informatics: Team Selection, Training, and Statistics – The Tale of Two Countries

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Abstract. The paper discusses the issue of supporting informatics (mainly focusing on programming) education through competitions for secondary school students. Competitions play an important role for learners as a source of inspiration, innovation, and attraction. The International Olympiad in Informatics (IOI) is the primary computer science competition for young students, up to the age of 20. The primary goals of the IOI are to stimulate challenges in Informatics among exceptionally talented young students from all over the world, and have them share scientific and cultural experiences. We describe the selection and training process in Israel and Lithuania. An overview of infrastructure and development of competitions from international and regional levels to the national one (Israeli and Lithuanian) is presented in short. In addition we provide some statistics from the years 2010 to 2014, such as: Israeli and Lithuanian medals, number of participants in the different stages of the training process, and age and gender distribution of contestants in the National contests. We conclude with a discussion comparing the IOI projects in both countries.

Keywords: learning through competition, programming contests, training, olympiads in informatics, IOI.

1. Introduction

The IOI – the International Olympiad in Informatics – is the primary computer science (CS) competition for young students, up to the age of 20. The IOI is one of several annual international youth olympiads, including: the IMO in mathematics, the IPHO in physics, the ICHO in chemistry, the IBO in biology, and the IAO in astronomy. The IOI is hosted every year by a different country. It started with 13 participating countries, in Bulgaria in 1989, and expanded to more than 80 countries today.

The primary goals of the IOI are to stimulate challenges in CS among exceptionally talented young students from all over the world, and have them share scientific and cultural experiences. Each participating country conducts a preparation process, and brings an IOI team which includes four contestants. In the IOI, the contestants compete individually in the course of two competition days, each involving three challenging algorithmic tasks, to be solved and programmed.

The task solutions require careful task analysis, insightful correctness and efficiency considerations, and skilful programming implementation. Creativity, competence in algorithmic topics (Verhoeff *et al*., 2006), and implementation accuracy are essential. The better half of the students in the two-day competition, win gold, silver, and bronze medals.

Teachers have noticed that competitions are very important for students to improve their skills in programming. Just the idea of participation in a competition is often enough to increase significantly students' motivation level to learn programming. The competition structure usually allows comparing students' work to that of their peers. These opportunities give positive evidence regarding the strength of one's own capabilities. International competitions are also very useful networking events both for students and teachers.

Different countries invest different amounts of effort and resources in preparing their IOI teams (e.g.: Diks *et al*., 2007, Casadei *et al*., 2007, Forisek, 2007, Kolstad and Piele, 2007), yet the preparation outlines seem similar. A call-for-participation engages an initial amount of interested students, from whom the top ones are chosen, through a selection and training process. In what follows, we briefly describe the selection and training process both in Israel and in Lithuania, and then display some statistics of this process and participation in the IOI.

2. The Selection and Training Process

2.1. *The Israeli Case*

In Israel, the IOI project is operated and supported by Tel-Aviv University, the Open University of Israel and the Ministry of Education. The primary objective of the project is to offer challenges in CS to motivated students, who show interest and competence in problem solving in general, and algorithmic problem solving skills in particular.

The project is composed of four stages: a regional competition; a national competition, an advanced training and team-selection stage, and the national team's preparation to the IOI. The different stages are operated by a small training team, of five to six trainers – the head coach and his deputy, a couple of high-school teachers, and a couple of former IOI contestants.

2.1.1. *Regional Competition*

The 1st stage is conducted at the beginning of the winter. It starts with a call-for-participation for the regional competition sent to high-schools and posted in the national CS teachers' website (maintained by the high-school CS inspector in the ministry of education). The interested students are referred to the project's website (The Israeli IOI Project Website), and are encouraged to prepare for the regional competition, by self-studying rather basic programming and data-structure constructs (e.g., recursion and trees) and solving previous national competition tasks. The goal of the regional competition is to offer algorithmic challenge to an audience as wide as possible; to engage CS secondary school teachers in posing the challenge; and to identify competent students, who will advance in the project activities.

A 5-questions questionnaire was posted in the website of the CS inspector of the Ministry of Education. The questionnaire was posted at a given time, which was a-priori told to all the secondary schools in Israel. Secondary school teachers, downloaded the questionnaire, and posed it to their selected students, as a 2-hour exam. Questions during the exam, about the exam tasks, were directed in real-time (phone) by the teachers to the training team. The students wrote their answers on exam sheets, which were downloaded from the internet. All the sheets were sent to the training team for grading. A couple of days after the exam, the solutions were posted, with broader perspectives of notions that appeared in the exam questions.

The teachers' role in this activity was to encourage their better students, and have them take the exam. They supervised their students during the exam, and sent to the team the student notebooks.

As one of our goals was to expose the project to as wide an audience as possible, we posed algorithmic tasks for which the required answers were not an algorithm, but rather the outcome of an algorithmic computation. This approach offers the opportunity of reaching students who are less acquainted, or even unacquainted with programming. The exam questions focused on mathematical and algorithmic insight, on which one had to capitalize her/his computation.

We invited to the next stage all those who obtained a score of 80+, plus students who obtained a lower score but nicely answered one or more of the insightful sections in the questions. We expected students to learn from our posted solution, and from our previous national competitions, in preparing for the next stage – the national competition.

2.1.2. *National Competition*

The 2nd stage is conducted in the late winter (February). It involves the national competition, which is a three-hour exam, with pencil and paper. The students are gathered together, and are asked to solve four algorithmic tasks, and provide a written description of their solution idea and their solution code, or pseudo-code (according to their preference). The goal of the exam is to identify the students that demonstrate the highest potential, primarily in problem solving. Thus, the CS knowledge required at this stage is relatively basic.

The first task of the national competition usually requires recursion, which may be implemented with a rather simple dynamic-programming scheme. The second task involves a mathematical game, or a similar task, whose solution is based on a hidden invariant property. The third and fourth tasks are more involved, in terms of the required insight and the solution scheme. Yet, the code required for each of the tasks is rather short. The students are explicitly directed to focus on task analysis, and carefully notice correctness and efficiency considerations. The exam format and example questions are described in a previous paper (Zur *et al.*, 2011). In grading their solutions, the team particularly examines their creativity, accuracy, and scientific discipline. They pay less attention to detailed programming features, as long as the criteria indicated above are met.

We select the best 30 students, plus possibly a few additional ones, in cases where there are females or students from remote schools that are close to the top 30. All these students are invited to the next stage.

2.1.3. *Advanced Training and Team-Selection Stage*

The 3rd stage is conducted in the spring. The objective in this stage is to teach the top 30 students more advanced algorithmic and problem solving features, and test them about these features. The top four students of this stage are chosen for the national team. This stage involves 5–7 practice days (one or two such days a week). It does not involve a camp (as offered in some other countries), but rather a day gathering in a computer lab, due to our limited resources.

Each practice day lasts 8–10 hours. Prior to that day, students are asked to study particular topics (e.g., basic graph algorithms). In the first part of the day, three algorithmic tasks are posed to program in five hours, which involve the indicated topics and the previous days' topics. The students are asked to both program their solutions and write on paper their solutions' underlying idea. At the end of this activity each student is interviewed about his/her solutions. The goal of the interviews is to examine their insight and extract potential errors and difficulties that arise and recur. In addition, the student programs are tested on diverse test-cases.

Following the interviews and the program evaluations, all the participants are gathered for a two–three hour discussion on the day's task solutions and their related CS topics. The discussion involves particular focus on insightful analysis, common errors, and essential efficiency considerations. The latter is particularly underlined, as many of the posed tasks may be solved in several ways, of different time and space complexities. The trainers strongly emphasize two elements: potential and recurring errors and algorithmic and problem solving features used in the day's task solutions, which are relevant beyond these tasks (e.g., particular task representations and illuminating perspectives). Some of these elements are described in papers and columns (Ginat, 2001, 2003a, 2003b, 2007).

At the end of the practice day, the students are asked to program at home alternative solutions that were discussed, and to further study the algorithmic and problem solving features that were examined. At the end of these 5–7 practice and evaluation days, four students that demonstrated the best accumulated performance, in both algorithmic problem-solving and programming, are selected to the national team. The rest of the students are encouraged to return in the following year and convince other students from their schools to join as well.

2.1.4. *National Team's Preparation to the IOI*

The 4th stage is conducted thereafter and usually lasts up to two months, until the IOI. In this stage, the team is directed to learn and practice the topics relevant for the IOI, solve previous IOI and additional olympiads' tasks, and thoroughly practice the programming features required in the IOI. The team members meet with the project trainers once every one or two weeks, practice task solutions, discuss solutions, and receive advice and tips from previous team members who competed in the IOI. A particular emphasis is put on one's selection of test-cases before submission.

2.2. *The Lithuanian Case*

The teaching of informatics has a long tradition in Lithuanian schools; a rich experience in the field has been accumulated (Dagienė, 2006). However we complain that in the last decade our schools have spent too much attention on application of information technologies. The education programme of lower secondary schools, starting with the fifth grade, includes a separate course on information technology (IT), a part of which is devoted to introduce programming using Logo or Scratch. Students have a possibility to choose an optional programming module in grades 9 and 10. After that they can continue with an advanced programming module in grades 11 and 12.

However students have possibility to obtain deeper programming skills while participating in various non-formal activities: Young Programmers' School (Dagys et al., 2006), olympiads and contests in informatics (programming). A combination of all these activities leads students to the IOI (Fig. 1).

2.2.1. *National Olympiad in Informatics*

The first Lithuanian nation-wide informatics olympiad was organized in 1990, i.e. the year after the first IOI in Bulgaria.

In the beginning the olympiad consisted of the three stages: the 1st is stage was organized in autumn in schools; the 2nd stage was conducted in December by municipalities (60 municipalities in Lithuania). The main goal of participants was to qualify for the next level competitions.

The 3rd stage, named as a national stage, was conducted in spring. Since 1993 the national stage has been split into two parts: the 3rd and 4th stages. Initially the 3rd stage was organized using e-mail, later and nowadays participants of the 3rd stage submit their solutions through a contest management system; the 4th – final-stage is an on-site con-

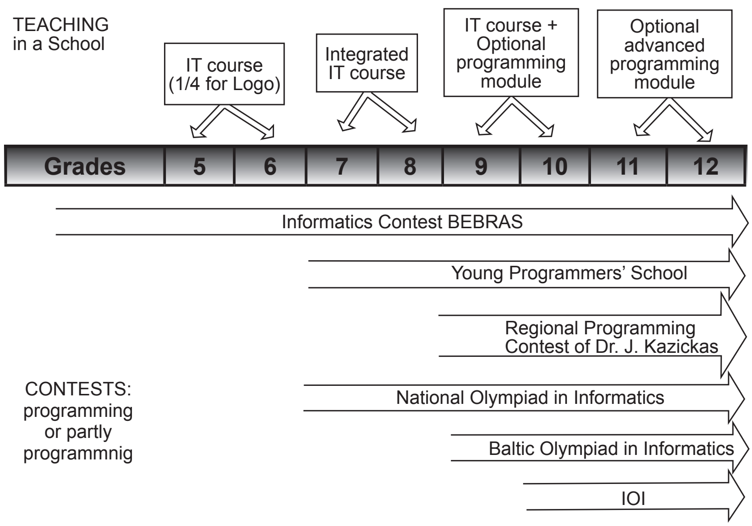

Fig. 1. Formal and non-formal ways of teaching programming in Lithuania.

test. The structure of four-stage-olympiad is more convenient and is used until now. In the each of the 1st–3rd stage students should solve three algorithmic tasks during a half of day (4–5 hours). The students are asked to provide their solution code and the description of the solution idea.

The final stage of the national olympiad is organized in a different region each year. Organizing the event in different regions not only allows the contestants to get to know the region but also gives a possibility to the teachers of local schools to look at the olympiad from inside – to observe how the final versions of tasks are being prepared, and to look closer at the contest system and the grading process.

About 50 participants from all over Lithuania are invited to compete in face-to-face exams. Students solve from 5 to 7 algorithmic tasks during two competition days (five hours each day). The competition days are combined with some leisure activities (sports, games, excursions, museums, etc.).

2.2.2. *Organizing on-Line Contests*

Twenty years ago the structure of the national olympiads in informatics was quite complicated. Each of the sixty municipalities in Lithuania designated winners of their competition for the national stage. As it was not possible to arrange an on-site competition for more than two hundred students, the 3rd stage used to be arranged in several selected municipalities at the same time.

A significant breakthrough became possible in 1993, when the computer network became available for several schools in each municipality. It was decided to organize the 3rd stage in each region using e-mail. Solutions were delivered through e-mails and afterwards graded using black-box testing for the ten years from 1993 until 2002.

The automatic contest management and grading system that allows the submission of programs via a web-interface during contest time, and checking whether they compile and comply with format requirements, has been used in Lithuanian olympiads since 2003.

All students of lower and upper secondary schools are invited to participate in informatics olympiads. Approximately 3000 students take part in 1st stage each year. The number of younger (grades 7–9) participants has significantly increased when a separate division for younger students was established and 30% of the places in the finals of the national competition were reserved for students from younger division. This motivated both younger students and their teachers.

2.2.3. *Baltic Olympiads in Informatics*

In order to ensure better preparation for the IOI and to strengthen regional relations, various regional olympiads are being organized. The Baltic Olympiads in Informatics (BOI) were established by the initiative of the three Baltic countries – Estonia, Latvia, and Lithuania – in 1995. Year by year six other Baltic countries (Denmark, Finland, Germany, Poland, Sweden and Norway) joined the BOI and now all these countries send their teams annually. The host countries still maintain the tradition of inviting guests to BOI. In 2005 Lithuania invited an Israeli team.

Compared to the IOI, the BOI is a short-term (the duration is 5 days) and inexpensive event. It has a cosy and good neighbourly atmosphere.

The organisation of BOI has changed over the years. To keep the event manageable, the number of contestants per team was decreased from 8 to 6.

Even though BOI is a mini-model of IOI it differs significantly. The organization of the scientific part of the BOIs is based on mutual trust of participating countries. The leaders of all the participating countries take part in proposing and selecting problems for the coming BOI. After draft problem formulations are presented, the problems are discussed via e-mail and each country takes part in vote for the problem set for the competition. Most of the problems are translated into native languages by the leaders before leaving for the BOI.

Each country is asked to submit at least one task proposal – with 9 participating countries there is no additional need for each country to come up with more proposals. Tasks are algorithmic in their nature:

1) Combinatorial search tasks where it is possible to go through all reasonable solutions (possibly with some optimisations) and choose the optimal solution.
2) Dynamic programming tasks where the problem can be divided into independent sub-problems.
3) Graph theory tasks where the problem can be transformed into a graph and solved by constructing a graph algorithm.
4) Mathematical tasks which include the tasks concerning arithmetic, geometry, number theory and probability.

Also unusual, innovative tasks which require an original non-traditional solution method or algorithm are very welcome. Even though all the tasks are of an algorithmic nature they represent cultural and methodical differences.

Automated contest and grading systems, mainly developed and maintained by the host country, are used to manage the contest. The neighbourly help of countries with more experience of managing contests to host countries with less or no experience makes it possible to host well organised contests in all countries.

During the competition leaders are involved in solving various problems which might occur, for example, some misrepresentation in the formulations of contest problems. This is a unique possibility for country representatives to gain experience in organizing scientific part of a small international olympiad (Poranen *et al.*, 2009).

The BOI is also a form of learning for its participants. The organizers of BOIs try to follow as close as possible the newest IOI trends in problem types, compilers, platforms and contest systems. It is not always possible to do that in national contests. Many students come to the BOI to gain international experience after participating in domestic contests. The BOI can be considered as a pre-arranged international form of learning.

2.2.4. *National Team's Preparation to the IOI*

The regional BOI serves as selection of students for the IOI (Gal-Ezer *et al.*, 2009). Usually Lithuania selects the best 4 students from the 6 students participating in BOI. The BOI is organized at least two months before IOI so there is still time for students to learn and practice the topics relevant for the IOI, solve tasks and practice the programming features required in the IOI.

A week long face-to-face training session is organized before each IOI, usually during summer time. In the training session not only the 4 IOI team students are invited to practise but also up to 10 best participants from the national olympiad that were not invited to the IOI team, especially the younger ones who are expected to be candidates for the IOI team in the future. Former IOI participants volunteer to work in the training session.

3. Some Statistics

This section presents some statistics regarding achievements of contestants, participation in the different stages of the IOI project, age and gender distribution of participants.

3.1. *Medal Distribution*

The main achievements of the IOI are medals. Achievements of both Israeli and Lithuanian teams are similar during years however last year was very successful for Israel – 4 medals including a gold one (Table 1). These achievements might be attributed to the increased funding that the Israeli IOI project received from the Ministry of Education in the year 2013. The funding enabled hiring additional trainers and organizing more extensive training sessions.

Table 1
Achievements of the Israeli and Lithuanian teams in the IOI

Year	Israel			Lithuania		
	Gold	Silver	Bronze	Gold	Silver	Bronze
2010			3		1	2
2011		2			1	2
2012		2	1		2	2
2013	1	2	1		1	
Total	**1**	**6**	**5**	**0**	**5**	**6**

Table 2
Participation in the Israeli IOI project

Year	Regional Competition	National Competition	Advanced Training and Team Selection
2010		251	30
2011	1442	674	22
2012	1767	359	33
2013	1131	263	32
2014	1283	386	37

3.2. *Participation in the IOI Project*

Table 2 shows the number of students who participated in the different stages of the Israeli project in the years 2010 to 2014. The regional competition began in 2011 therefore we do not have data for the number of participants in the regional competition in 2010. These students come from approximately 20 to 70 different high schools located all over the country.

The number of participants in the Israeli national competition is usually 250 to 400 except in 2011 where the number of participants was much higher (Table 2). This can be attributed to the fact that in that year we started to conduct the regional competition which exposed many students to the olympiad project.

The number of participants in the different stages of the Lithuanian Olympiads in Informatics is presented in Table 3.

3.3. *Age and Gender Distribution in the IOI Project*

The majority of the participants in the Israeli national competition are 11th and 12th grade students (17–18 years old). In all the years except 2012, 11th grade had the highest number of participants (Fig. 2). The reason that the number of participants in the 12th grade

Table 3

Participation in the Lithuanian IOI project

Year	1st stage	2nd stage	3rd stage	Final	Training
2010	~2200	~750	303	53	11
2011	2220	748	336	50	11
2012	2217	750	330	51	12
2013	2507	791	345	49	10
2014	2319	943	298		

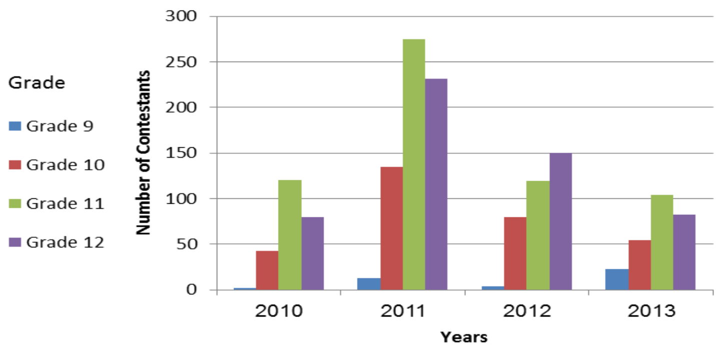

Fig. 2. Grade distribution in the Israeli national competition.

is a bit lower than the number of participants in the 11th grade is because the 12th grade students are busy at the time of the national competition with the high school matriculation exams.

Table 4 shows the percentage of female and male participants in the national competition of the Israeli IOI project in the years 2010 to 2013.

The percentage of female participants in the national competition has decreased from 30% to 13%. The percentage of female students who select CS in high school is approximately 30% (Gal-Ezer *et al*., 2009).

In spite of our efforts throughout the years to increase female participation, we found that girls are less attracted to competitions and therefore they avoid their participation in the competition. Throughout the years very few girls have been selected for the advanced training stage but the team trainers have invited the girls who achieved best results in the national competition to participate in that stage. We tried to increase teacher's motivation and involvement in the IOI project, particularly in attracting more girls to the different stages of the project (Dagienė and Skūpienė, 2004).

Fig. 3 shows the age distribution of students who participated in the 2nd stage of the Lithuanian project in the year 2011 to 2014.

In Lithuania traditionally programming is a "boys" subject. Very few girls have chosen to participate in the National Informatics Olympiad because it is a purely programming contest. A very small number of girls participate in the 1st and 2nd stages, almost no girls in the 3rd and 4th stages.

Table 4
Gender Participation in the Israeli national competition

Year	Male	Female
2010	70%	30%
2011	80%	20%
2012	77%	23%
2013	87%	13%

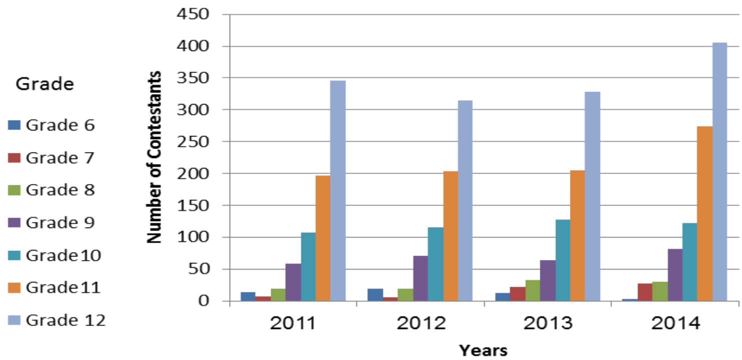

Fig. 3. Grade distribution in the Lithuanian national competition (2nd stage).

4. Summary and Discussion

The IOI project stimulates challenges in CS among exceptionally talented young students and enables sharing of scientific experiences. The tasks, with which the students are faced, require careful task analysis, insightful correctness and efficiency considerations, and skilful programming implementation. Creativity, competence in algorithmic topics, and implementation accuracy are essential. This extracurricular activity promotes talented students and benefits CS studies in participating countries.

Both countries put a lot of effort into the selection and training process. The achievements of both countries are similar. Some of the notable differences are:

Lithuania involves the teachers in the first stages of the selection process (particularly in the 1st and 2nd stages), while in Israel most of the work is done by the training team. Israel has tried in the past to involve the teachers but most of the teachers avoid involvement because they feel that they do not have enough experience with such questions and this puts the teacher in an uncomfortable position (Zur *et al*., 2012). We believe that with a proper teacher training, the teachers will feel more comfortable to collaborate with the training team. This collaboration will contribute both to the selection and training process.

The final stages of the training process in Lithuania include participation in the regional olympiad (BOI Olympiad) while in Israel the participation in regional olympiads has begun only recently. There is no doubt that this participation contributes greatly to the final training and selection process.

As we can see from the above sections, each country developed a unique selection and training program. Fig. 4 summarizes the selection and training stages in both countries.

All in all, the IOI project in Israel is rather modest. The training team's hope is to extend their resources and activities in the coming years, expand the training team, hopefully with additional IOI veterans, and attract a larger number of interested students (males and females) already in the early stages.

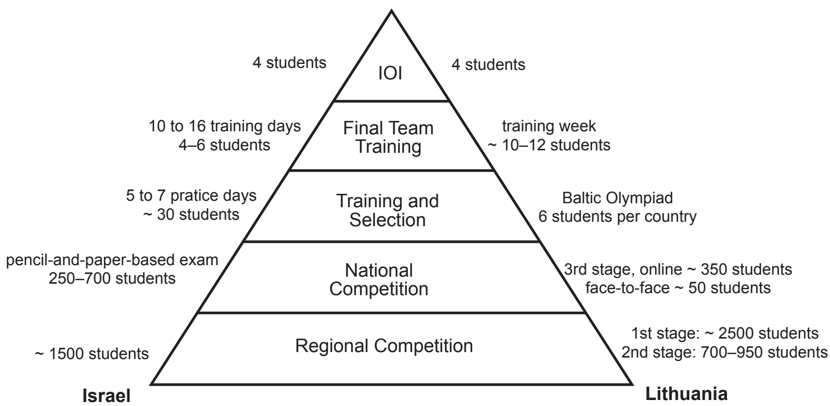

Fig. 4. Competition, selection and training stages in both countries.

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